Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
	)	
Federal-State Joint Board on Universal Service	)	CC Docket No. 96-45
	)	
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COMMENTS OF APPLE COMPUTER, INC.

Apple Computer, Inc. ("Apple") hereby comments on the Notice of Proposed Rulemaking and Order Establishing Joint Board ("NPRM"), issued March 8, 1996.

Apple has long been the leading provider of technology for education. For well over a decade, it has been committed to offering tools and services that incorporate best practices for using technology to enhance teaching, learning, and communicating. These tools not only help teachers to provide the foundation skills of a good basic education, they also enable students to develop the skills they will need for the future, including interpreting data, collaborating, communicating, and using computer technologies both individually and as part of a larger group.

Apple's commitment to education goes well beyond merely supplying equipment. Apple is deeply involved in the technological, social, and cultural issues that influence educational reform globally. Through its Apple Classrooms of Tomorrow ("ACOT") technology research group, Apple has learned that technological tools can be used to motivate students and foster their abilities, revolutionize the way they learn, and ease their access to the world around them. Students benefit not merely through improved performance in test scores, writing ability, and other traditional measures of achievement, but also by becoming more socially aware and confident, better able to communicate effectively and work collaboratively, more independent as learners, and with a positive orientation to the future. New technologies, used properly, can

transform teachers from lecturers to guides/mentors who are able to participate in the education process with their students.[1]

Apple, therefore, has a strong interest in the Commission's implementation of the Telecommunications Act of 1996 (the "1996 Act") provisions dealing with the delivery of telecommunications and information services to schools and libraries. Access to telecommunications networks can be a tool for transforming and equalizing education opportunities, providing three basic benefits to students and teachers:

- Communications: Networks make it possible for students, teachers, and faculty to communicate with others both in an individual classroom and across schools, communities, states and nations.

- Information Access: Networks allow students to reach beyond the physical limitations of their classroom to obtain information relevant to their learning. Through networks, students can access school library systems and CD-ROM data bases. In addition, they can use the Internet to obtain information stored on computers at any other networked location on the planet.

- Share Resources: Networks enable students to access remote files, share files for collaborative projects, share and publish classroom projects, and connect to printers and other devices. Using network modems or connections to on-line services and the Internet, this sharing of information resources can be engaged in on a local or even global basis.

Based upon its experience in the field of education, and in order to enable schools to take full advantage of telecommunications and information technologies, Apple urges the Commission to interpret Section 254 of the 1996 Act with the following principles in mind.

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[1] See "Changing the Conversation About Teaching, Learning & Technology: A Report on 10 Years of ACOT Research" (1996) (attached).

1. All students should have equitable access to advanced telecommunications resources.

The rules defining the services to be made available to schools and libraries under Section 254(h)(1)(B) of the 1996 Act should seek to assure that all students will have access to telecommunications services without regard to household income, school budget, geography, school size, or other factors that distinguish students and schools from one another. This fundamental principle of equity underlies several of the other principles discussed below, including the recommendations that:

- the Commission adopt a broad definition of available services — thereby making it possible for each individual school to obtain the mix of services best suited to its needs and resources;

- a mix of wireline and wireless options be provided — thereby making it possible for schools and service providers to use the most efficient, least-costly alternative to satisfy a given set of requirements; and

- the rules clearly provide for network sharing — thereby making it possible for schools and libraries to minimize the costs of their networks by sharing capacity, on a non-profit basis, with other users.

In addition, the principle of equity argues in favor of Commission action to prevent "redlining." Because Section 254(h)(1)(B)'s basic obligation to provide service on a discounted basis applies only to telecommunications carriers serving a "geographic area," the Commission should define the concept of "geographic area" carefully. In particular, it should seek to maximize the number of carriers that are deemed to be serving a given geographic area — especially rural and high-cost areas — and, thereby, to increase the number of options available to schools and libraries within each geographic area.

2. Services should be defined broadly and inclusively, and the definition of services should evolve over time.

The Commission must take care to assure that schools — both today and in the future — have access to a full range of telecommunications services. Different schools will require a different mix of functionalities, and each should be able to make the choices best suited for its student body, in light of its

available physical, financial, and other resources, without being unnecessarily constrained by an overly-restrictive "menu" of covered services. Moreover, educators are still at a relatively early stage of understanding how best to use telecommunications and information technologies to enhance learning. Schools should be given the widest possible latitude to experiment with alternative services, to implement new technologies as they become available, and to modify their usage of these resources as their understanding of the interaction between technology and learning matures.

For this reason, the Commission should require that a wide range of telecommunications services be included within the definition of "universal service" for purposes of Section 254(h)(1)(B) of the 1996 Act. This definition should include:

- a high bit rate "best of class" connection linking the school building(s) to the telecommunications infrastructure;
- a full range of additional digital services, with bandwidths ranging from 128 K to at least 45 MB;
- both fixed and mobile digital services; and
- both dedicated and dial-up facilities.

In addition, each school should be able to obtain telecommunications services and CPE on an unbundled basis.[2]

The set of services encompassed within the "universal service" rubric should be capable of supporting the following needs of students and teachers:

- Curriculum development using communications technology;

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[2] In a recent Notice of Proposed Rulemaking, the Commission proposed that non-dominant interexchange carriers be permitted to bundle CPE and long distance services. Notice of Proposed Rulemaking, Policy and Rules Concerning the Interstate Interexchange Marketplace, CC Docket No. 96-61 (March 21, 1996). Even if such a rule is adopted generally, schools and libraries will require the flexibility to create their own combinations of CPE and telecommunications services and, therefore, should continue to have the ability to obtain these elements on an unbundled basis.

- Integration of telecommunications and information capabilities, including functions such as netbrowsing, videoconferencing, and virtual reality, into the educational process;
- Professional development/teacher training;
- Technical support;
- Parental linkage to the schools to become more involved in what their children are accomplishing;
- Personnel applications; and
- Student record and assessment.

The services available to schools and libraries should evolve over time to keep pace with developments in technology and communications markets, and this evolution should become effective with the minimum amount of regulatory intervention possible. For example, as few as three to four years ago few would have said that all schools should have Internet access. Today, however, a reasonably high-speed link to the Internet is generally viewed as a fairly basic requirement. Similarly, computers originally were introduced into schools through centralized computer labs or media centers. Today, however, there is widespread recognition that computers are substantially more valuable when they are available to students wherever, whenever they want to learn — whether in the classroom, on a field trip, or at home.

An evolving definition of available facilities and functionalities is essential to assure that schools continue to have access to technologies and services that are not considered significant today. This is important not only in its own right, but also because schools will be better able to afford telecommunications and information equipment if they are operating in the mainstream market, rather than having been sidelined into outdated technologies by an overly-restrictive definition of the services which they may receive on a discounted basis.

For this reason, Apple supports the Commission's focus on the functionalities that should be supported through the universal service

mechanism and on the facilities required to provide those functionalities,[3] as well as the Commission's statement that it will not prescribe a specific technical standard for each funded service.[4] Overly restrictive definitions which focus solely on the "service" rather than the underlying functionalities and facilities — and, in particular, those that define a "service" with reference to a fixed set of technical specifications — will tend to become obsolete over time, sometimes quite rapidly. In addition, rigid definitions over-emphasize the characteristics of the service rather than recognizing that these services are merely inputs to the educational process, not ends in themselves, and must be capable of being molded by educators to meet the needs of a particular set of students at a particular place and time. Schools and libraries, therefore, will be better served by a set of rules that define services in non-rigid terms and with reference to the broader, evolving market of available services.

3. Rights should be clear and requirements minimal.

Schools and libraries will not have extensive legal or administrative resources to wade through a complex set of rules and regulations governing their rights to obtain telecommunications services on a discounted basis. For this reason, it is essential that the Commission write its rules in the clearest possible language, that carriers be directed to provide understandable information to those potentially entitled to discounted services, and that additional regulatory burdens be minimized.

Apple, therefore, agrees that the Commission should seek to harmonize its discount methodologies with the states' methodologies.[5] In addition, it should adopt a simple certification (*e.g.*, a brief letter from an authorized school official) to deal with the 1996 Act's requirement that discounted services must be used for educational purposes and may not sold, resold, or otherwise transferred for money or any other thing of value.[6] Finally, the Commission should adopt clear rules — with examples, and perhaps even including a process for obtaining FCC opinion letters — that expressly permit schools and libraries to share their

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[3] NPRM at ¶ 80.
[4] Id.
[5] NPRM at ¶ 83.
[6] NPRM at ¶ 84.

networks with others, including others who are not themselves eligible to receive support.[7] Such sharing not only will permit interoperation among different users, but also could be used to reduce the overall cost of the network and to provide opportunities for schools and libraries to create partnerships with others around them. As a result, any rules that restrict sharing should be limited to the maximum extent possible, and where needed should avoid imposing burdensome recordkeeping, monitoring, or other obligations.[8]

4. Schools and libraries should have access to both wired and wireless facilities and services.

As discussed above, a broad range of solutions will be required to meet the communications needs of schools and libraries across the country, both now and in the future. Wired and wireless services each are suited to satisfying different needs, and both should be made available.[9]

5. Efforts to enhance access to advanced telecommunications and information services should seek to capitalize upon competition and market developments.

In addition to granting schools and libraries the right to obtain telecommunications services on a discounted basis, the 1996 Act also instructed the Commission to establish competitively neutral rules to enhance, to the extent technically feasible and economically reasonably, these institutions' access to advanced telecommunications and information services.[10] Apple agrees that access to information services will be vital in meeting the needs of tomorrow's

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[7] NPRM at ¶ 86.

[8] In particular, requirements to allocate capacity among those eligible for a subsidy and those who are not eligible for a subsidy is problematic in a digital world. For example, a school installing a network to provide full motion video would require a high bandwidth link, whether the school intended to use the video capability 1 hour per week or continuously every day. If the school is entitled to obtain that link at a subsidized rate, and if it intends to use that link for educational purposes, it should not matter that it is permitting another user to share capacity on that link, particularly where the sharing is done to enhance the efficiency and cost-effectiveness of the school's network.

[9] In addition, unlicensed products and services can meet some of the needs of schools and libraries. For example, in light of recent and proposed unlicensed allocations, unlicensed devices soon will be able to support very high capacity local area networks and, if authorized by the Commission, longer-distance "community network" links. Unlicensed devices, however, are not directly implicated by universal service policies since they are not a service provided by a telecommunications carrier.

[10] 1996 Act, Section 254(h)(2)(A).

educators and students. Information services often provide the content that make the "pipes" of the telecommunications network come alive for students and contribute much of the value that will enhance educational opportunities.

The Commission's efforts to promote the availability of information services to schools and libraries should focus on the competitive marketplace. For example, the computer and information services markets have been characterized by often substantial price competition, resulting in computers and information services that not only are powerful and easy to use, but also are affordable. In the years to come, the computer and information services markets — free from the inhibiting forces of regulation — will continue to innovate and create new, affordable educational, informational, and entertainment services.

The Commission should recognize the substantial benefits provided by robust competition in the computer and information services markets and should avoid any impulse to regulate these markets in an effort to promote access by schools and libraries to advanced information services. Such regulation not only would be counter-productive, but also would be inconsistent with the intent of the 1996 Act. Instead, the Commission should use its powers to augment the strengths of the marketplace. For example, the Commission should allocate adequate, suitable spectrum for unlicensed services — a low-cost, flexible means for meeting many of the communications needs of schools and libraries and of enhancing these institutions' access to, and ability to use, advanced information services. In addition, it should work with the Board responsible for governing the Telecommunications Development Fund to promote access to capital for small businesses in the telecommunications industry — including the computer, data transmission, software, programming, advanced messaging, and electronics businesses — and to stimulate the development of new technologies. Finally, it should continue to be vigilant in promoting fair competition in the information services market by assuring that information service providers have equitable access, via the local telephone exchange, to their customers.

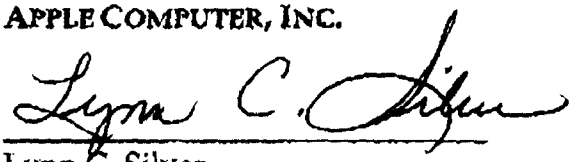
CONCLUSION

Apple's experience in education technology for the past decade has given it a unique perspective into several of the issued raised in the universal service

NPRM. Apple urges the Commission to implement the NPRM in accordance with the principles outlined above.

Respectfully submitted,

APPLE COMPUTER, INC.



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April 12, 1996

"The students don't get tired of working on the computer. They actually ask for things to do. In all of my years of teaching, I never had anyone ask for another ditto."

–Robert Howell,
Fourth-grade Teacher,
Dodson Elementary School,
Nashville, Tennessee

What happens to students...

By the end of the first year, students' behavior and attendance improved, along with their attitude toward themselves and toward learning.

Performance also improved in several ways:

- Test scores indicated that, despite time spent learning to use the technology, students were performing well—and some were clearly performing better.
- The students wrote more, more effectively, and with greater fluidity.
- Some classes finished whole units of study far more quickly than in past years.

Dispelling widespread myths, the researchers found that instead of isolating students, access to technology actually encouraged them to collaborate more than in traditional classrooms. And instead of becoming boring with use, technology was even more interesting to students as they began using it for creating and communicating.

Over time, independent researchers found that students in ACOT classrooms not only continued to perform well on standardized tests but were also developing a variety of competencies not usually measured. ACOT students did the following:

- Explored and represented information dynamically and in many forms.
- Became socially aware and more confident.
- Communicated effectively about complex processes.
- Used technology routinely and appropriately.
- Became independent learners and self-starters.
- Knew their areas of expertise and shared that expertise spontaneously.
- Worked well collaboratively.
- Developed a positive orientation to the future.

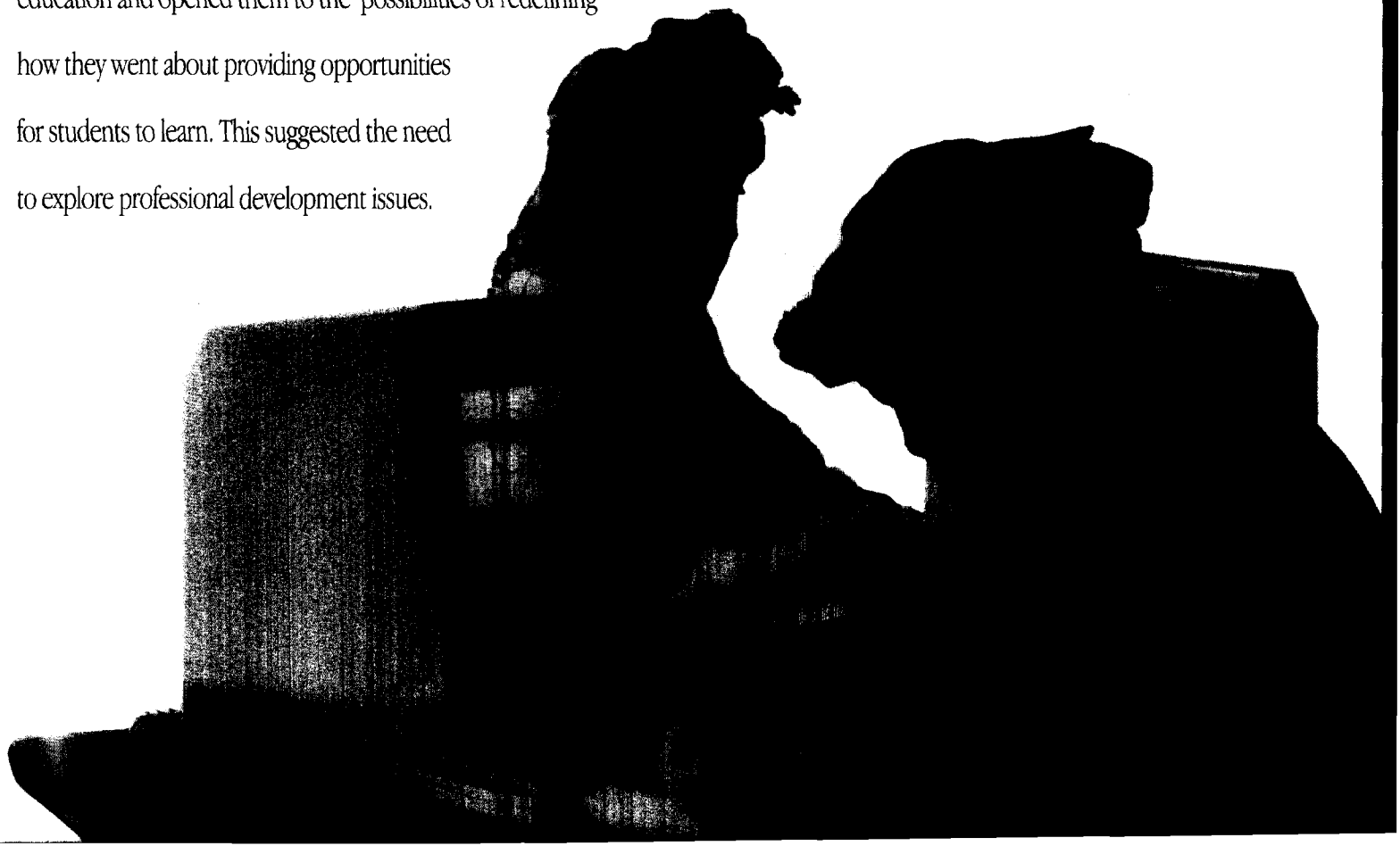
ACOT has revitalized the teaching process tremendously. It has also been the catalyst for a transition from blackboards and textbooks to a method of instruction where students can explore, discover, and construct their own knowledge.

—Barry Stebbins, Science Teacher, West High School, Columbus, Ohio

...and teachers?

These findings suggested the need for more research, both in the area of assessment and in ways to develop similar environments for learning in other schools.

As ACOT teachers became comfortable with the technology, they reported they were enjoying their work more and feeling more successful with their students. Over time, they also reported that they interacted differently with their students—more as guides or mentors and less like lecturers. In fact, their personal efforts to make technology an integral part of their classrooms caused them to rethink their most basic beliefs about education and opened them to the possibilities of redefining how they went about providing opportunities for students to learn. This suggested the need to explore professional development issues.



The ACOT classrooms have become a model for interdisciplinary studies, team teaching, and addressing individual learning styles. These are all concepts that have been around for many years, but that a not easily put into practice. Introducin technology into the classroom provide catalyst to actually put these concept

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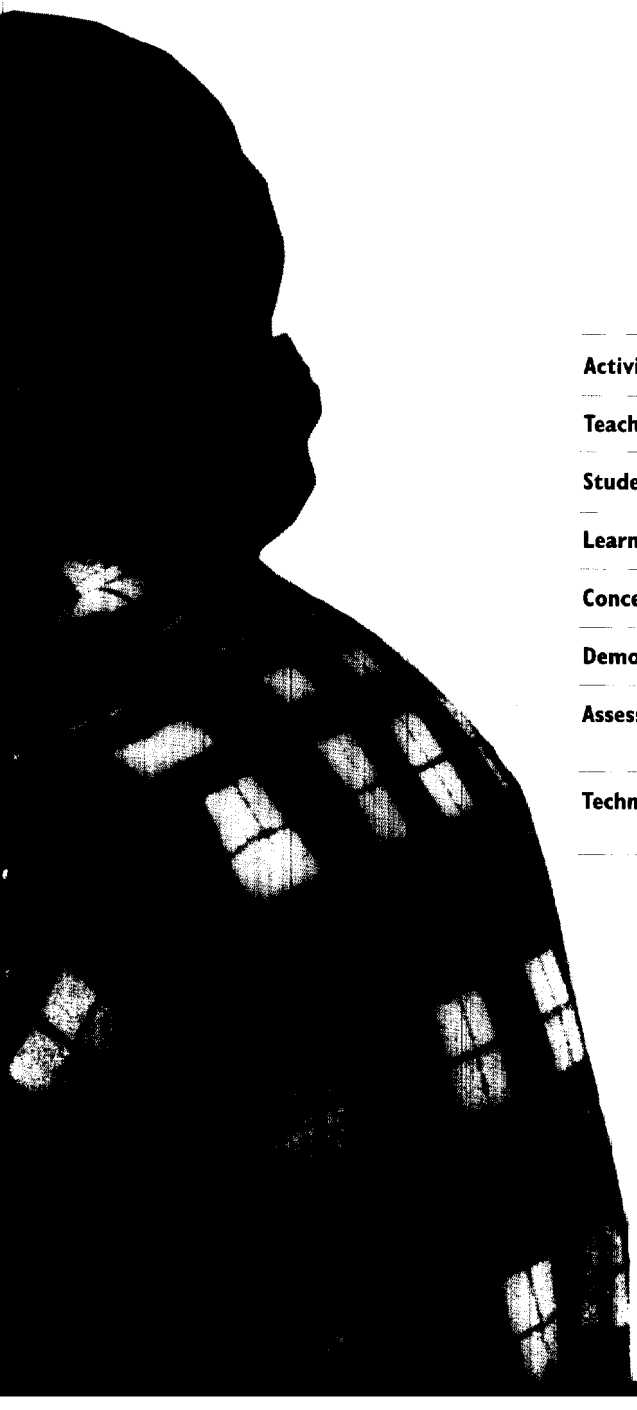
into practice and helps both students and teachers to succeed in dramatic ways.

—Jane Pratt, Supervisor, Department of Instructional Technology, Columbus Public Schools, Columbus, Ohio

# of technology



Not surprisingly, teachers and researchers found that an array of tools for acquiring information and for thinking and communicating allows more children more ways to become successful learners. But they also found that the technology itself is a catalyst for change—encouraging fundamentally different forms of interactions among students and between students and teachers, engaging students systematically in higher-order cognitive tasks, and prompting teachers to question old assumptions about instruction and learning.

	Traditional (instruction)	Extended (knowledge construction)
Activity	*Teacher-centered and didactic*	*Learner-centered and interactive*
Teacher role	*Fact teller and expert*	*Collaborator and sometimes learner*
Student role	*Listener and learner*	*Collaborator and sometimes expert*
Learning emphasis	*Facts and replication*	*Relationships and inquiry*
Concept of knowledge	*Accumulation*	*Transformation*
Demonstration of success	*Quantity*	*Quality*
Assessment	*Norm-referenced and multiple guess*	*Criterion-referenced and performance portfolios*
Technology use	*Seat work*	*Communication, collaboration, information access, and expression*

The chart above shows the shift that occurred in classrooms as the ACOT teachers extended their traditional views of teaching and learning—from instruction to knowledge construction.

What's important to know for today's schools?

Early on, we found that with powerful, multipurpose tools and a learning environment that balances the appropriate use of direct instruction with a collaborative, inquiry-driven, knowledge-construction approach, students can achieve far beyond today's expectations. We also discovered that teachers are the key to creating such learning environments. And we found that they need broad administrative support both to create these environments and to sustain them.

Although few schools offer the degree of technology access found in ACOT classrooms, our research raises some important points for today's discussions about education. These ideas, though powerful, are also so simple that we sometimes refer to them as "the cutting edge of common sense."

Learning needs to be meaningful. We need to balance curriculum-based instruction with opportunities for students to use an inquiry-based, collaborative approach to solve meaningful problems. Problem-based learning lets students build on their own knowledge and incorporate new information with what they have already learned. And when technology is available to students, it not only opens up opportunities to solve problems, it also provides additional tools for communication and collaboration.

Examples abound of ACOT students being engaged in meaningful learning activities. For instance, fourth-graders capped a semester of technology-enriched project-based learning by initiating their own writing project. During the last three weeks of the school year, they designed, wrote, and produced "how-to" handbooks for the incoming fourth-graders—to help the new students more easily learn how to use ACOT's technology-based tools.

This experience has made me take risks. I've decided the worst that can happen is I make mistakes and I need to ask others for help. I think if I show that I take risks and make mistakes in teaching, my children will feel more comfortable doing the same in learning.

—Participant in the ACOT Teacher Development Center program

As you work into using the computer in the classroom, you start questioning everything you have done in the past, and wonder how you can adapt it to the computer. Then, you start questioning the whole concept of what you originally did.

— Paula Fistick, Math Teacher, West High School, Columbus, Ohio

Students at the ACOT high school site, engaged in an interdisciplinary study of their city, constructed a mechanized, 12-foot-square, scale model of the downtown area—and honed their skills in mathematics, language arts, and robotics as well as in critical thinking, problem solving, and resource management. Replicating the project the following year, the next class added a level of complexity. After videotaping the entire process, they used the video output to create an interactive, computer-driven exhibit for the city's science museum.

Technology is a catalyst for change. Bringing technology into the classroom levels the playing field between teachers and students—creating an unfamiliar challenge for teachers. This effect is compounded when the students know more about the technology than their teachers—or simply learn to use it faster. Although teachers may initially be uncomfortable in that situation, they also discover unexpected benefits. For example, many teachers develop more empathy for students because they, too, are experiencing being learners. They also develop new respect for those students who learn enough to become "local experts" in the technology area, and often rely on them to help others.

As teachers become comfortable with a shift in classroom roles, they may start extending their idea of what it means to be a teacher. If they're supported, they may also change their approach to teaching and learning—from curriculum-centered to learner-centered, from individual tasks to collaborative work, and from passive learning to active learning.

As a result of my experiences at the center, I am now allowing my children to have more control of the equipment. Before, I would have the children type on the word processor, and I'd save it for them. Then, in the evening, I would print their things for them. Now I let them do it all.

—Participant in the ACOT Teacher Development Center program

Teachers progress through stages as they learn how to incorporate technology in classroom environments.

We observed that teachers' approach to the use of classroom technology evolves through a few orderly stages: entry, adoption, adaptation, appropriation, and invention. And we found that certain kinds of support help speed that evolution: mentors who are further along in the process, opportunities for reflection, and encouragement to question their beliefs about teaching and learning.

A framework for collaboration can support teachers in the change process.

When teachers have an opportunity to collaborate with peers, for example in developing or assessing classroom activities, they have a wealth of experience on which to draw. Yet because teaching is essentially an individual activity, teachers are not used to this kind of collaboration. So they usually begin with different approaches, points of view, and vocabularies. A common language and framework for discussion makes collaboration on classroom activities more productive and also supports professional growth.

ACOT staff and teachers came up with the following terms and associated questions for beginning a conversation about change:

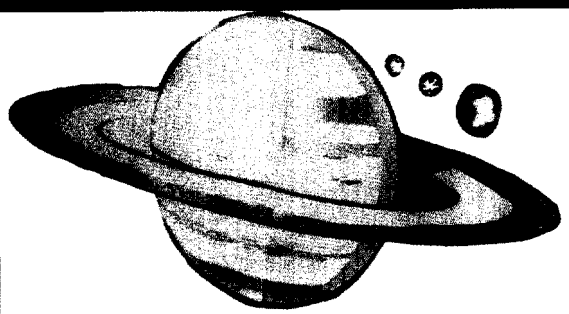
Standards. What objectives are set for learners? Why is it important for a student to accomplish an objective? How does the objective fit into an overall district, state, national, or international framework?

Tasks. What is the nature of the student work required by the teacher?

Interactions. Who talks and works with whom? Who initiates interactions?

Situations. How are time, space, and place—and the experience and concerns of the learner—used to support activities?

Stage	Examples of what teachers do
Entry	*Learn the basics of using the new technology.*
Adoption	*Use new technology to support traditional instruction.*
Adaptation	*Integrate new technology into traditional classroom practice. Here, they often focus on increased student productivity and engagement by using word processors, spreadsheets and graphics tools.*
Appropriation	*Focus on cooperative, project-based, and interdisciplinary work—incorporating the technology as needed and as one of many tools.*
Invention	*Discover new uses for technology tools, for example, developing spreadsheet macros for teaching algebra or designing projects that combine multiple technologies.*



Tools. What materials are provided to support the representation of ideas?

Assessment. How is student learning demonstrated? How do students, teachers, parents, and administrators know that productive work is accomplished—that learning standards are met or exceeded?

Situated professional development is a powerful agent for change.

When teachers see other teachers and students in the day-to-day challenges of real school, they begin to say "I can do this." So, for example, they are most willing to adopt new ideas about learning and technology when their observation and work is "situated" in real classrooms where students are successfully engaged in the routine use of technology.

The ACOT Teacher

In 1985, when ACOT staff began exploring ways to help teachers use technology effectively in their classrooms, they tried various teacher development approaches. Over the years, they found that those that had the most impact did the following:

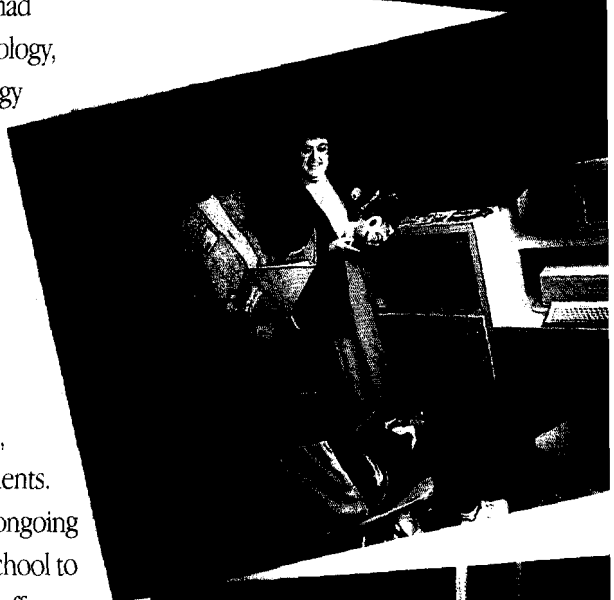
- Involved small-group collaborations among teachers
- Took place in working classrooms
- Built on teachers' existing knowledge about curriculum and practice
- Provided opportunities to experiment and reflect on new experiences
- Provided ongoing support to help implement change and innovation

Visitors to ACOT sites remarked on the differences they observed between traditional teacher roles and what they saw in the ACOT classrooms, and they often asked how the ACOT teachers learned the instructional techniques they use.

In 1988, in response to frequent requests for a "recipe for technology staff development," the teachers and staff at the Nashville ACOT site designed a professional development program that would provide opportunities for teachers to learn about integrating technology within the context of classroom practice.

By 1989, two-teacher teams from local schools began attending three-day programs at the ACOT site. During that time, the participants observed accomplished ACOT teachers and discussed the approach to teaching and learning that the ACOT teachers had adopted. They also had hands-on experiences with technology, discussed their goals for technology integration, and developed a proposal for an effective instructional use of technology in their own classroom. Overall, the three-day program not only provided them with new information, but also encouraged them to think about creating more collaborative, active, student-centered environments. The ACOT coordinator provided ongoing follow-up support, visiting each school to talk with the teachers about their efforts to use technology as well as to change their role in the classroom.

Following two years of positive response to this pilot program, the ACOT Teacher Development Centers project was funded by the National Science Foundation—in partnership with ACOT and the participating school districts. The project began in September 1992.



Development Centers Project

The biggest benefit of the Teacher Development Centers is that secondary teachers see first-hand what dramatic improvements can be made with instructional methods other than "lecture, recitation, seat work." They can see that it is possible to implement positive changes with technology as a catalyst.

—Elizabeth Sidorenko, ACOT Teacher Development Center Coordinator, Columbus, Ohio

Characteristics of Successful Staff Development

Constructivist learning environment. Although some teachers are initially uncomfortable in the learner-centered environment of the ACOT Teacher Development Centers, most quickly adapt, taking advantage of the opportunity for exploration and discovery to construct their own knowledge about the role of technology in instruction.

Situated staff development. Working in real classrooms with real students makes staff development participants better able to see that what they are learning can be useful in their own classrooms. The classroom observations not only provide participants with models of teaching strategies, new ideas, and validation for what they were already doing, they also stimulate discussions of educational issues.

Time for reflection. When teachers experience a different kind of learning environment, such as that found in the ACOT Teacher Development Centers, they need time to think about the new information they're getting. Personal reflection, while participating in a group discussion or writing in a personal journal, helps teachers to question their own beliefs and to begin the process of change.

Specific plans for change. To structure their observations and experiences, and to facilitate the transfer of new ideas into their own classrooms, participants at the ACOT Teacher Development Centers plan a project that they will implement upon returning to their schools. The major purpose of the project is to get teachers to use their existing resources.

Immediate and ongoing follow-up support. Because new skills need to be reinforced with practice and supported with feedback, the teacher development program includes a two-part follow-up component. First, the centers require that teachers attend in teams, so they can provide each other with both practical and emotional support when they return to their schools. In addition, the project coordinators provide frequent feedback to the participants about the implementation of their projects, and they encourage an ongoing conversation about instructional change.

Looking at 10 years of ACOT

Just as the original "What happens when...?" question prompted a variety of other questions, so, too, the ACOT research divided into several strands. The longitudinal, site-based strand that grew out of the original question has evolved into a professional development project—the ACOT Teacher Development Centers. Another strand focused on the development of cutting-edge technologies that integrated new ideas about teaching and learning. To facilitate the necessary collaboration among researchers, teachers, and students, ACOT established additional short-term research sites in dozens of other classrooms nationwide.

Here are some of the major themes of the research and the directions it has taken. (Note: For the most part, the prototype software used in these projects is not commercially available.)

... as a work in progress

There's been a significant increase in the body of knowledge about how people use technology for teaching and learning, and ACOT researchers have made valuable contributions. But countless questions are still unanswered, and untold more have yet to be asked. This is a work in progress. Stay tuned.

Collaboration. We know that using technology both encourages students to collaborate and aids in collaborative work. What kinds of collaborative environments and tools are most helpful?

- Marlene Scardamalia and Carl Bereiter (Ontario Institute for Studies in Education) created a computer-based environment that supports students in the manipulation and construction of information as they collaborate on projects.
- Brian Reilly (UC/Berkeley, now at Apple) designed a HyperCard stack that manages student work in a portfolio format and allows teachers and students to add comments.

Communication. When learners in the past encountered problems, they had access to only the teacher's knowledge and information from textbooks and the library. What happens when students have access to other experts, on-line sources of information, and colleagues?

- With the Technical Education Research Center (TERC) and the Public Broadcasting System (PBS) we created MediaFusion, a project that combined the capabilities of television (timely stories) with computers (interactivity) to create environments where students explore important issues and discuss their discoveries with students in other schools.
- Karla Kelly (Lucasfilm) developed an interdisciplinary curriculum—based on the Foxfire model—that motivates middleschool students to explore their own cultural heritage and to create interactive projects that reflect their life experiences.

research...

- With the San Francisco Exploratorium and a local school district, we are investigating how elementary school teachers can use a media-rich environment to enhance communication, collaboration, and inquiry.

Multiple representation of ideas. What kind of learning tools can we develop that take advantage of the computer's power to represent ideas in multiple forms?

- Jere Confrey (Cornell) developed a tool to aid in the discovery approach to teaching calculus. Function Probe allows students to construct relationships between tables, graphs, and equations easily and interactively—and to work with functions in a concrete rather than an abstract way.
- Barbara Buckley (Stanford) created an interactive multimedia simulation to give high school students a deeper understanding of physiology.
- Roy Pea and Christina Allen (Institute for Research on Learning) created MediaWorks, a multimedia database and composing tool that allows students to research, create, analyze, and synthesize a wide array of information.

Intelligent applications and modeling. What are some of the ways to use computing power to support students when they're solving problems?

- John Anderson (Carnegie Mellon University) created an intelligent computer tutor for geometry that provides a visual toolkit for developing geometric proofs and gives feedback at each step.
- Bowen Loftin (University of Houston) developed Intelligent Physics Tutor, a physics-tutoring environment that "observes" each student solving problems and "learns" how best to respond to his or her errors and how to provide useful guidance through the curriculum.

Information analysis What happens to learning and motivation when we give students access to the very tools, or the same kinds of tools, that are used by professional researchers?

- Chris Hancock (Technical Education Research Center) explored the use of technology to help teach middle school students how to use data to solve real problems. He used TableTop, a visual database environment for young students, and developed interdisciplinary, inquiry-based activities.
- Richard Greenberg (University of Arizona) taught teachers how their students could use digital image processing tools to derive information from satellite photos—thus gaining authentic science experiences.
- Gene Stanley (Boston University) created hands-on activities and simulations so that high school math and science students could be "doing real science" as they learn about probability and random processes in nature—specifically by studying fractals.
- Karen Price (Harvard) developed a video manipulation tool that allowed teachers and students to use video to explore the context in which language occurs.

Assessment. We know that students and teachers are developing new competencies, many of which are not measured by current tests. How can we identify them accurately and measure them objectively?

- Eva Baker (UCLA) examined the effectiveness of traditional measures of student achievement and student self-concept at capturing changes in ACOT students over time. She also explored objective ways to do portfolio assessment.
- Robert Tierney (The Ohio State University) conducted longitudinal observations of ACOT high school students, focusing on the way they write, organize their work, and attack new problems. He also examined students' self-assessment.
- Allan Collins (Northwestern University) and Jan Hawkins (Center for Teaching and Learning) investigated the use of video in performance assessment of complex learning, such as in physics.
- Midian Kurland (Education Development Center, now at Apple) examined the use of TextBrowser, a technology-based language arts assessment tool that teachers could also use to generate activities based on the students' own work.
- Roy Pea and Jeremy Roschelle (Institute for Research on Learning) created VideoNoter, a software tool that supports researchers in their efforts to analyze videotapes of classroom learning situations. Using this tool, researchers can annotate and later search and gather video segments on a common theme.

Where to get more information

ACOT research reports, along with videotapes that document three ACOT projects are available through Apple's StartingLine materials distribution program. Call 1-800-825-2145 for more information or to place an order.

The ACOT Research Portfolio—1990 includes these reports:

- *ACOT Evaluation Study: First- and Second-Year Findings*
- *Teacher Beliefs and Practices Part I: Patterns of Change*
- *Teacher Beliefs and Practices Part II: Support for Change*
- *Teaching in High-Tech Environments: Classroom Management Revisited*
- *Development of Teacher Knowledge and Implementation of a Problem-based Mathematics Curriculum*

Part number: LO1561A Cost: $5.00

The ACOT Research Portfolio—1992 includes these reports:

- *Computer Acquisition: A Longitudinal Study of the Influence of High Computer Access on Students' Thinking, Learning, and Interactions*
- *The Negotiations of Group Authorship Among Second-Graders Using Multimedia Composing Software*
- *Partnerships for Change*
- *The Relationship Between Technological Innovation and Collegial Interaction*
- *Trading Places: When Teachers Utilize Student Expertise in Technology-Intensive Classrooms*

Part number: L0328LL/A Cost: $5.00

The ACOT Research Portfolio—1994 includes these reports:

- *Creating an Alternative Context for Teacher Development: ACOT's Two-year Pilot Project*
- *Creating an Alternative Context for Teacher Development: The ACOT Teacher Development Centers*
- *Environments That Support New Modes of Learning: The Results of Two Interactive Design Workshops*
- *MediaFusion: A Tool That Supports Learning Through Experience, Reflection, and Collaboration*
- *Student Engagement Revisited: Views from Technology-Rich Classrooms*

Part number: L00804/A Cost: $7.75

Two-page summaries of many of the research reports are available free, either by fax or electronically on eWorld. To order by fax, call Apple Education at 1-800-800-APPL (2775) and choose the fax option. Then follow the instructions to order a catalog of available documents.

To find the summaries (and some of the full reports) on eWorld, look in the Learning Center.

"Wireless Coyote" is a videotape that follows middle school students on a science field trip into the Arizona desert. The students use wireless communications and mobile computers to collect and analyze data and to share their findings with colleagues at other locations.
Part number: APL 870 Cost: $8.00

"Cloud Forest Classroom: An Investigation into Wireless Collaboration" is a videotape that shows how students on a biology field trip to Costa Rica's Monteverde Cloud Forest used Macintosh PowerBook computers connected by radio frequency modems to inquire and collaborate.
Part number: APL 882 Cost: $8.00

"MediaFusion: Coast-to-Coast Collaboration" is a videotape that shows how junior high students on opposite coasts of the United States share thoughts and theories about global warming. Using Macintosh computers, the students compose QuickTime movies with embedded graphs that support their positions. Then they exchange these messages via satellite with their peers across the country.
Part number: APL 883 Cost: $8.00

For information about Apple Education products, programs, and services, call1-800-900-APPL (2775).

Apple Education information can also be located on the Internet at http://www.info.apple.com/education and on eWorld.

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...and the thousands of ACOT students and their families.
Thanks for joining us in this first decade of discovery.

ACOT has been a pioneer in providing a national test bed for innovation in advanced educational technologies and in education research. It has fostered new models of uses for technology in education and inspired teachers, researchers, and industry alike.

—Roy Pea,
Dean of the School of Education and Social Policy and John Evans Professor of Education and the Learning Sciences, Northwestern University

Apple Classrooms of Tomorrow (ACOT) is a 10-year-old research and development collaboration that unites public schools, universities, research agencies, and Apple Computer, Inc. In ACOT classrooms, students and teachers have immediate access to a wide range of technologies, including computers, videodisc players, video cameras, scanners, CD-ROM drives, modems, and on-line communications services. In addition, students can use an assortment of software programs and tools, including word processors, databases, spreadsheets, and graphics packages. In ACOT classrooms, technology is viewed as a tool for learning and a medium for thinking, collaborating, and communicating.

ACOT research has demonstrated that the introduction of technology to classrooms can significantly increase the potential for learning, especially when it is used to support collaboration, information access, and the expression and representation of students' thoughts and ideas. Realizing this opportunity for all students, however, requires a broadly conceived approach to educational change that integrates new technologies and curricula with new ideas about learning and teaching, as well as with authentic forms of assessment.

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